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Improving quantity and quality of castor bean oil for biofuel growing under severe conditions in Egypt

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Abstract

Castor bean (*Ricinus communis*) has emerged as a biofuel crop with potential for its production in marginal land with application of treated sewage water. Some projects in different scales are established to produce castor bean seeds, but additional research is needed to develop the optimal management programs, including the nutrients which help plants to resist the severe conditions such as marginal (bad) soil and the irrigation by treated waste water, reaching to the effect on the produced oil. A field experiment was conducted in El-Gabal El-Asfer Farm, Cairo, Egypt, during 2012 and 2013 growing seasons to evaluate the effect of two rates of foliar K-Amino fertilizer on the productivity as well as the quality characteristics of castor bean oil irrigated by three water regimes of secondary treated sewage water. Results indicated that the maximum seed yield (1026.68 kg fed.$^{-1,}$ one feddan equals 4200 m^2) was obtained from spraying plants by 100% of K-amino rate under the irrigation with 75% of the calculated Etc. Castor oil properties indicate low pour points which make this biofuel a good alternative in winter conditions or in the low temperature. The produced oil under 75% of Etc (recommended evapotranspiration) water regime showed good flow properties. It indicates that castor oil biofuel also could be used as petroleum diesel additive improving both environmental and flow behaviour of the mineral fuel. Generally, producing castor bean oil by spraying of K-amino fertilizer under the irrigation of 75% and/or 100% of Etc water regime is more appropriate to produce biofuel.

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Keywords: castor bean yield; castor bean oil characteristics; water regimes; treated sewage water; nutrients; k foliar

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1. Introduction

Castor bean (*Ricinus communis*) is belongs to Euphorbiaceae family, common to all the warm regions of the world. It is a fast growing fibrous non wood plant native to eastern Africa, especially the Ethiopian area. This oil is highly viscous, its coloration ranges from a pale yellow to colourless, it has a soft and faint odor and a highly unpleasant taste. As an example the castor plant has been known to man for ages. Castor beans have been found in ancient Egyptian tombs dating back to 4000 B.C and during that time, the castor oil was used thousands of years ago in the wick lamps for lighting. Castor bean is grown as an annual in temperate zones and as a perennial in the tropics. This crop is cultivated for its seeds, which contain up to 45% of fast-drying natural oil rich in ricinoleic acid used mainly in medicines and industry. World annual production of castor is 1.1 million tons of seeds and its yield is around 0.7 t ha^{-1} $year^{-1}$. The main producers are India, Brazil and China. In Brazil this crop is cultivated in all regions [1][2].

Biofuel obtained from castor oil has a lower cost compared to the ones obtained from other oils due to its solvability in alcohol transesterification occurs without heating [3]. The biodiesel produced from castor bean also satisfies the relevant quality standards without regard to viscosity and cold filter plugging point [4]. In addition, biofuel produces fewer particulates, hydrocarbons, nitrogen oxides and sulphur dioxides than mineral diesel and therefore reduces combustion and vehicle exhaust pollutants that are harmful to human health [5].

Egypt is facing fresh water shortage due to rapidly increasing demands of population growth, which is about 2 million per year. The expansion of agricultural production in the desert area is essential to meet the growing demand for food production which has further accelerated the increment of pressure on the available fresh water resources. Therefore, there is an interest in using poor quality water for irrigation. One such source of poor quality irrigation water is treated sewage water, which contains large amount of organic materials and some inorganic elements essential for plant growth. Also it may contain non-essential heavy metals which when present in large amount could be harmful if it be consumed in excess quantities through food chain [6]. Although the use of treated waste water is restricted for irrigation of food crops, this can be a good source for irrigation of non-food crops.

This research work aims to increase the quantity of castor bean oil as well as the quality of using it as a biofuel by using K-amino foliar fertilizer.

2. Materials and methods

A field experiment was carried out at El-Gabal El-Asfer Farm, Cairo, Egypt, during 2012 and 2013 growing seasons to study the effect of foliar fertilizer treatments on the quantity and quality of castor bean (*Ricinus communis*) seeds as well as some characters of its oil to produce biofuel diesel. Thirty six of cultivated trees were randomly chosen to apply the three treatments of treated sewage water as a percentage of Etc (50, 75, and 100 % of the recommended Etc in Cairo region for castor bean crop) along 2012 and 2013 growing seasons and the foliar K-Amino 100% and 50% of the recommended dose (3 and 1.5 mm/lit, respectively) were applied three times per every growing season, two weeks in between before and during the flowering stage of plants. There were not any other fertilizers added, only the nutrients in the water resource (treated sewage water). The trees were cultivated in the dimensions of 3 m between trees and 3 m between rows. The statistical analyses were complete randomized design with 4 replicates, Results were statistical analyzed by the methods as described by Snedecor and Cochran (1989) [7]. Some chemical analyses of treated sewage water are presented in Table 1.

The seeds were collected two times per the growing season from the selected experimental trees, and the shelling %, oil %, yield of seeds and oil (kg/fed., one feddan equals 4200 square meter), where 1 feddan equal 2400 m^2, as well as some characteristics of oil, which confirmed that castor oil is suitable n ne for producing biofuel, such as specific gravity, density, viscosity, flash point, sulphur percent, pour point, and ash.

Although biofuel has many environmental advantages it also has some performance drawbacks. In cold conditions the behaviour of the biofuel normally is even worse than that of petroleum diesel. At low temperatures biofuel and diesel form wax crystals that can restrict the flow in a vehicle fuel system clogging fuel lines and filters. Castor oil biofuel exhibits different operation conditions.

Table 1. Some chemical analyses of secondary treated sewage water.

	Parameters	Values
	pH	7.19
	EC (dS/m-1)	1.12
Soluble cations (meq/L)		
	Ca++	2.5
	Mg++	2.5
	Na+	6.5
	K+	2.0
Soluble anions (meq/L)		
	Co-3	----
	HCO-3	5.9
	CL-	5.0
	SO-4	0.8

Cold flow properties

Pour point is important parameter for low temperature operation. Pour point refers to the temperature at which the amount of wax out of solution is sufficient to gel the fuel and indicates the lowest temperature at which the fuel can flow [8]. Properties of biofuel were tested according to ASTM D 6751 standard.

3. Results

Interactive effect of three amounts of treated sewage water within two K-amino doses was found significant on shelling % ($p \leq 0.05$). Also significant differences of the individual studied treatments ($p \leq 0.05$) were found, (Table 2). Results clearly showed clear response of castor plants to the treated water regimes as well as the K-amino. Maximum value of shelling percent (55.4%) was determined in 75% of Etc at 100% K-amino dose (Table 2). Seed productivity (kg/fed., one feddan equals 4200 square meter), oil %, and oil yield (kg/fed.) were increased by increasing K-amino foliar from 0 to 100% rate (from 0 to 3 mm/l) as well as increasing irrigation water regime from 50% to 75% of the Etc, but there were not significant differences for the studied parameters between the two water regimes 100% and 75% of Etc (as treated waste water regimes), so it could save 25% of the irrigating water for another uses or expand the cultivation area.

With respect to seed yield per feddan, the significant interaction between water regimes and K-amino rates was found ($p \leq 0.05$) and varied between 1026.6-295.0 kg fed.$^{-1}$ (Table 2). The maximum seed yield (1026.6 kg fed.$^{-1}$) was obtained from spraying plants by 100% of K-amino rate under the irrigation with 75% of the calculated evapotranspiration (Etc) for the castor bean crop in this region. Whereas, minimum seed yield (295.0 kg fed.$^{-1}$) was recorded by irrigating plants with 50% of the calculated Etc and spraying plants by zero K-amino (control K treatment). Furthermore, the other studied parameters have the same trend of Taylor et al. (2005) [9]. The increase in oil yield which was obtained by the increment of K-amino levels might be due to the role of K fertilizer and amino growth regulator in stimulating vegetative growth and keeping the flowers on the trees [10]. These values are in line with previously reported by many authors [11-16].

In the current study, the crude oil content varied between 27.75 and 21.05% among interaction of studied treatments. As well as the highest oil yield was obtained under 75% of Etc water regime and spraying by 100% K-amino. These results are in the same concern of many reviews [12, 15, 17-19]. On the other hand Deligiannis et al. (2009) [20] in a research obtained 40.3% oil in some castor bean cultivars.

Depending on the oil productivity, four oil samples (high yields) were selected for the analysis of oil properties as illustrated in Table 3. The efficiency in the process for the production of biofuel was in the range of 80-82%. Table 3 shows a comparison between the properties of different samples under the experimental conditions to study their suitability for biofuel production; the analyses were made in the laboratory. Castor oil properties indicate low pour

points which make this biofuel a good alternative in winter conditions or in the low temperature. The produced oil under 75% of Etc water regime showed good flow properties. It indicates that castor oil biofuel also could be used as petroleum diesel additive for improving both environmental and flow behaviour of the mineral fuel. It was found that sulphur % was higher as the K-amino rate decreased. It is important to highlight that pour point decline as more K-amino rate is added. This implies a higher level of stability at lows temperatures. Generally, producing castor bean oil by spraying of K-amino fertilizer under the irrigation of 75% and/or 100% of Etc water regime is more appropriate to produce biofuel.

Table 2. Effect of water regimes and foliar fertilizer type on productivity and quality of castor bean.

Water, % of the Etc (recommended evapotranspiration)	Fertilizer	Shelling %	Seed productivity, kg/fed.	Oil %	Oil yield, kg/fed.
50	Control	42.15	295.02	21.55	63.57
	Amino 50%	41.50	293.68	21.85	64.21
	Amino 100%	42.10	311.64	21.94	68.33
75	Control	43.10	468.04	21.50	100.63
	Amino 50%	52.10	823.16	22.45	184.80
	Amino 100%	55.20	1026.68	27.75	284.92
100	Control	44.00	489.28	21.05	102.99
	Amino 50%	53.00	805.60	22.00	177.23
	Amino 100%	54.50	1079.20	24.78	267.47
L.S.D. at 5% level		0.73	62.22	0.83	17.61
Mean of values under the effect of water regime treatments					
100 % of the Etc		50.50	791.36	22.61	182.56
75 % of the Etc		50.13	772.63	23.90	190.12
50 % of the Etc		41.92	300.11	21.78	65.37
Mean of values under the effect of fertilizer treatments					
Control		43.08	417.45	21.37	89.06
Amino 50%		48.87	640.81	22.10	142.08
Amino 100%		50.60	805.84	24.82	206.91
L.S.D. at 5% level of Water treatments		0.85	41.62	0.59	13.58
L.S.D. at 5% level of fertilizer treatment		0.42	35.92	0.48	10.17

Table 3. Castor bean oil properties for biofuel production.

Water regime	K-amino foliar fertilizer	Specific gravity	Density, kg/m3	Viscosity, mm2/s	Flash point, ºC	Sulphur %	Pour point, ºC
100 % of the Etc	50 %	0.8010	0.84	5.56	148	0.0015	-4
	100 %	0.8013	0.80	5.20	146	0.0011	-5
75% of the Etc	50 %	0.8009	0.92	4.55	147	0.0016	-4
	100 %	0.8013	0.91	4.56	145	0.0011	-6

4. Conclusion

Spraying castor bean trees by 3 mm/l K-amino improves the seed as well as oil productivity. The produced oil under 75 % of Etc water regime showed good flow properties. Also, it indicates that castor oil biofuel also could be used as petroleum diesel additive improving both environmental and flow behavior of the mineral fuel.

References

[1] Chiaranda, M., A.M. Andrade Jr. And G.T. Oliveira, 2005. A produção de biodiesel no Brasil e aspectos do PNPB. Escola Superior de AgriculturaLuiz de Queiroz. USP, Brasil, pp: 32.

[2] Athanasios, H.G. and A.N. Georgios, 2001. The potential use of *Ricinuscomminis*L. (castor) stalks as a lignocellulosic resource for particleboards. Industrial Crops and Products, 13(3): 209-218.

[3] Conceição, M.M., R.A. Candeia, F.C. Silva, A.F. Bezerra, V. FernandesJr and A.G. Souza, 2007. Thermoanalytical characterization of castor oil biodiesel. Renewable and Sustainable Energy Reviews, 11(5): 964-975.

[4] Jeong, G.T. and D.H. Park, 2009.Optimization of biodiesel production from castor oil using response surface methodology. Appl. Biochem. Biotechnol., 156: 1-11.

[5] FAO, (2010): Climate-Smart' Agriculture – Policies, Practices and Financing for Food Security, Adaptation and Mitigation.Food and Agriculture Organization of the United Nations, Rome.

[6] A. A. Abd El-Kader, M. M. Hussein, and A. K. Alva, 2012.Response of Jatropha on a Clay Soil to Different Concentrations of Micronutrients. American Journal of Plant Sciences, 3, 1376-1381.

[7] Snedecor, G. W. and Cochran, WG. (1989), *Statistical Methods, Eighth Edition*, Iowa State University Press.

[8] Prakash, C.B., 1998. A Critical Review of Biodiesel as a Transportation Fuel in Canada. Environment Canada.

[9] Taylor, R.S., Weaver, D.B., Wood, C.W., Santen, E.V., 2005. Nitrogen application increased yield and early dry matter accumulation in late planted soybean. Crop Sci., 45: 854-858.

[10] Al-Thabet, S. S., 2006. Effect of plant spacing and nitrogen levels on growth and yield of sunflower (*Helianthus annuus* L.). J. King Saud Univ., Agric. Sci., 19(1): 111.

[11] Kittoch, D.L., Williams, J.H., 1967. Castorbean production as related to length of growing season. I. Effect of date of plant desiccation. Agronomy Journal, 59: 438-440.

[12] Blanckenburg, D., Creaner, H.D., 1971. Handbuch der Landwirtschaft uncl Ernaehrung in der Entwicklungslaender. Band 2. Ulmer. Stuttgart. P 355.

[13] Babagiray, Z., 1989. Güneydoğu Anadolu projesi (G.A.P) alanında hintyağı bitkisinin (*Ricinus communis* L.) önemli zirai karekterleri üzerinde araştırmalar. Ankara Üniversitesi Fen Bilimler Enstitüsü, Doktora tezi, Ankara.

[14] Oplinger, E.S., Oelke, E.A., Kaminski, A.R., Combs, S.M., Doll, J.D., Schuler, R.T., 1990. Castor Beans. http://www.hort. purdue.edu/newcrop/ duke_energy/Ricinus_communis.html (Erişim Tarihi: 18.09.2009).

[15] Labalette, F., Estragnat, A., Messéan, A., 1996. Development of Castor Bean Production in France. Progress in New Crops, ASHS Press, Alexandria, VA, pp. 40-342.

[16] Rastegar, M. A., 2005. Zeraate Giyahane Sanaatii. Berahmand Publishing, 1(7): 258-266. Tehran, Iran.

[17] Shams, A., Moursi, M. A., Ahmed, S.S., 1967. Effects of nitrogen and spacing on castor bean in sandy soils in Egypt. Cairo University. U.A.R. National Research Centre and Faculty of Agriculture, pp. 61-64.

[18] Armstrong, W.P., 1982. The Castor bean. http://waynesword.palomar. edu/plmar99.htm. (Erişim Tarihi: 12.11.2009).

[19] Brigham, R.D., 1993. Castor, return of an old crop. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York. pp. 380-383.

[20] Deligiannis, A., Anastopoulos, G., Karavalakis, L., Mattheou, D., Karonis, F., Zannikos, S., Stournas, E., 2009. Castor (*Ricinus communis* L.) seed oil as an alternative feedstock for the production of biodiesel. Proceeding of the 11th International Conference on Environmental Science and Technology. Chania, Crete, Greece. Demirel, E., 2007. Hintyağından.